The Evaluation of the "No-Wind" Airtightness of the Apple Hill Homes

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Summary

An attempt was made to perfect an analytical method for determining the "wind offset", the mean dynamic wind pressure which affects airtightness test results. In total,3 separate equations were evaluated to determine if it is possible to improve the data fit and provide a calculated wind effect that can accurately,and consistently,account for wind effects on the building envelope. The test data employed for this purpose was extracted from airtightness testing records on Apple Hill, a subdivision of energy efficient houses in Kanata, Ontario.

Unfortunately, none of the experimental equations produced consistently reliable results. Both the exponent(representing the slope of the air flow vs. pressure graphs), and the calculated offset pressure, were often beyond generally accepted limits.

As a further qualifier, the airtightness tests at Apple Hill were run in sets of three, during a period of an hour. Wind and temperative conditions during the hour of testing were usually consistent. No offset equation reflected this consistency.

The new analytical approach incorporating coefficients did manage to significantly improve data fit when compared to the standard equation specified in the Canadian General Standards Board Draft Standard 149-GP-10M for Airtightness testing of buildings.

Further testing may show that on-site observation of the offset will give more realistic results. Changes in test procedure, however, will not aid in the re-calculation of an offset for existing data.

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Introduction

"The Analysis of Airtightness Test Data with Wind Influence" is a paper prepared for Energy, Mines, and Resources Canada by the Saskatchewan Research Council, in July, 1982. In the paper, it was proposed that the standard air tightness equation,

$$Q = CP^n \qquad \text{Equation (1)}$$

Where Q is air flow
P the pressure across the envelope
C is referred to as the coefficient
n is referred to as the exponent

be modified to allow for wind effects on the test data. The suggested equation is:

$$P = A\,Q^B + C \qquad \text{Equation (2)}$$

Where A is the coefficient
B is the exponent
C is the offset pressure due to the wind, measured in pascals.

The paper included a means of determining this "C" term, by minimizing the square of the error between data points and calculated values. It included an iteration procedure in the paper, plus some worked samples.

With assistance from Professor J. Knight of Carleton University, equation (2) was examined and revised. The intention was to speed up convergence of the iteration, plus reduce the number of anomalies. As a result, a third equation was suggested :

$$Q = D(P-E)^F \qquad \text{Equation (3)}$$

Where D is the coefficient
E is the offset pressure in pascals
F is the exponent

This equation was programmed to minimize $\sum (LnQ_{meas.} - LnQ_{calc})^2$, whereas the SRC equation (2) minimizes $\sum (P_{meas.} - P_{calc})^2$. Equation (3) uses the same terms to optimize the fit as the standard equation (1), but fits three coefficients instead of two.

A fourth equation, with a flow offset, was also tested. This equation is of the form:

$$Q = R + SP + TP^{\frac{1}{2}} \qquad \text{Equation (4)}$$

Where R is the offset flow
SP is the term for laminar flow
$TP^{\frac{1}{2}}$ is the turbulent term

Procedure

Equations 1-4 were programmed on a Osborne computer, in BASIC (see Appendix A). Equation 2 was also programmed on a SHARP PC1211 (see Appendix C for example).

Equations 1 and 4 can be solved directly, while the two pressure offset equations, 2 and 3, require iteration for solution. Some iterations failed to converge. In those cases, it was possible for the standard equation to fit the data points better than the theoretically more accurate equations with three coefficients.

The results of each test were tabulated on computer printouts and a sample of these is reproduced in Appendix B. (A summary of all data is presented in Table 1), with the various coefficients rearranged for comparison. The SRC equation was chosen as the basis for comparison, so for the Q (STAND) or equation 1, and Q (OFFSET) or equation 2, the coefficient was manipulated to allow a direct comparison to the SRC coefficient. The slopes of the Air Flow vs. Pressure graphs (n,F, and N) are directly comparable. The values labelled E and C are the predicted offset pressures, in pascals.

The predicted flows from the derived equations are shown, as well as the onsite measured flow. Below these columns are the results for total squared error, total squared log error, and correlation coefficients. Due to the differences in optimization of the equations, it is not always true that the highest correlation coefficient also has the lowest squared error or squared log error.

Technical Discussion

The data produced by programming is too great to reproduce in its entirety. A sample of 20 tests is shown in Appendix B.

The STANDARD data is for equation (1). The results for both slope and correlation differed slightly from those derived by the Retrospectors' SHARP program used in Apple Hill reports. The difference was generally much less than 1%. Over the variety of analysis methods used, this crude equation fit the data points best in 6% of the tests.

The OFFSET data is for equation (3). It failed to converge in some tests, within the limit of 100 iterations. Further efforts to refine the equation would undoubtedly produce more efficient calculations. The calculated pressure offset term (E) varied widely, and showed little or no consistency even among test data from tests conducted on the same afternoon. The pressure offset also had no direct relation to the airport wind speed recorded at the time of the test. However, equation (3) did manage to produce the best data fit in 26% of the tests, (using the highest correlation as the measure of best fit).

The data labelled EYER in Appendix B, is from the original wind offset equation (2)(prepared by the Saskatchewan Research Council). The results were

similar to those of the OFFSET equation in their inconsistencies. However, the offset terms, E and C, showed little agreement in both sign and magnitude. This equation was examined exhaustively by Retrospectors prior to consultation with Prof. Knight, as some of the offset pressures ranged from 10 to 40 Pa.

Such high pressure effects do not agree well with the observed wind affects on site, or with the well-recorded pressure plane data. During the Apple Hill airtightness tests, rarely would the pressure offsets be greater than 5 Pa. More over, in all cases, four pressure averaging taps were positioned around the test house, while recording pressures for airtightness testing. This procedure should significantly reduce the pressure offset.

In Apple Hill during neutral pressure plane testing conducted during similar conditions, pressure tests (P_{in}-P_{ont}) were taken at the first floor level, in most houses, in both phases. As can be seen in Appendix D , Phase 1 (the winter phase) showed a mean maximum pressure difference of 1.23Pa, at a mean wind speed of 13kph and mean temperature difference of 17°C. In the summer tests, Phase 2, without the stack effect to cause pressure difference, the mean maximum pressure difference is only 0.5 Pa., at a mean wind speed of 13kph. Both the first floor pressure tests and the airtightness tests used pressure taps positioned approximately

one metre above grade. Because of the averaging effect of the four taps in airtightness testing, one would expect that the pressure offsets, at the fan level, would be even lower than those from the neutral pressure plane tests.

No manipulations reduced the C terms of equation (2) to uniformly reasonable levels. The basic equation seems ill-conditioned, as small changes in data can create large changes in the C term (see Appendix C). This is probably also true of equation (3).

Equation (4), with the flow offset, produced the best correlation in 59% of the tests. It often had the best fit, by a wide margin over all others. In cases where another equation produced a better fit, it was usually only in the fourth decimal place. However, the same inconsistencies were apparent in the results: the offset term was rarely steady through consecutive tests on one house; the S and T terms were sometimes negative, which is difficult to explain; and the "no-wind" terms did not necessarily resemble each other in test data collected on the same house from different Phases in the Apple Hill testing schedule. Some reproducibility of terms in tests on a single house, should be required, to validate any wind effect equation.

Table 1 to 3 are samples of the data produced. The figures shown are truncated after three significant digits except for the correlation. Table 1 contains all the depressurized, unsealed tests of both phases. This includes tests conducted by two different technicians, and using two types of

depressurization equipment(a calibrated ring and a bell-mouthed nozzle).

Table 2 shows the results for equation (4) applied to the depressurized, unsealed tests. As the "S" terms are small, they have been multiplied by 10^3 for the table.

Table 3 shows three houses, in both phases, where the equipment, procedure, and technician were identical for the tests. Hopefully, this eliminates any possibility of error resulting from discrepencies in test procedure or equipment calibration. In this table, the only obvious conclusion is that the standard test results produced with equation (1) show the most consistent results from one test phase to the next.

Table 1: Comparison of Results for Depressurized, Unsealed Tests

House No.	Phase	$C^{(-1/N)}$	$D^{(-1/F)}$	A	OFFSETS E	OFFSETS C	SLOPES n	SLOPES F	SLOPES N	CORRELATION COEFFICIENTS STANDARD	CORRELATION COEFFICIENTS OFFSET	CORRELATION COEFFICIENTS EYRE
1	1	66.0	62.6	73.8	4.75	-9.64	.597	.512	.772	.9873	.9878	.9855
	2	95.0	103.	97.5	2.77	.866	.589	.505	.561	.9986	.9987	.9888
2	1	65.8	66.7	64.3	-2.52	7.15	.793	.872	.585	.9901	.9895	.9898
	2	69.5	73.0	79.3	2.81	4.79	.692	.586	.516	.9970	.9983	.9983
3	1	65.1	64.6	77.4	.684	-14.6	.614	.601	.886	.9865	.9866	.9844
	2	99.2	96.8	98.7	-7.53	-13.8	.650	.831	.979	.9972	.9982	.9983
4	1	N.A.										
	2	143.	131.	130.	-15.6	-12.9	.635	.964	.915	.9957	.9974	.9974
5	1	66.1	65.8	65.5	.509	.631	.528	.520	.521	.9975	.9975	.9975
	2	83.5	87.6	83.5	2.76	-.713	.656	.568	.674	.9980	.9975	.9979
6	1	75.9	80.2	85.4	3.74	6.53	.667	.544	.461	.9946	.9970	.9965
	2	89.3	96.1	90.2	3.20	.590	.638	.537	.620	.9956	.9955	.9957
7	1	86.1	83.7	83.7	-5.78	-6.13	.619	.783	.793	.9978	.9997	.9997
	2	93.7	99.1	92.5	4.33	-3.64	.633	.527	.718	.9957	.9950	.9956
10	1	51.5	56.6	51.1	4.66	-2.22	.575	.406	.658	.9880	.9880	.9874
	2	66.3	65.9	65.4	-4.57	-3.25	.611	.755	.719	.9977	.9981	.9981
11	1	69.6	69.1	67.5	10.9	4.95	.566	.345	.474	.9933	.9945	.9942
	2	104.	113.	107.	5.81	2.66	.744	.589	.672	.9977	.9979	.9981
12	1	87.7	85.9	83.5	-10.9	-3.93	.637	.950	.769	.9951	.9960	.9963
	2	112.	114.	165.	N.A.	-82.9	.631	.977	2.23	.9814	.9862	.9894
13	1	68.1	61.4	61.1	12.4	12.0	.490	.315	.324	.9942	.9965	.9965
	2	91.6	115.	97.2	5.46	1.92	.590	.418	.527	.9917	.9935	.9928
14	1	57.2	75.0	76.8	-18.8	-20.9	.664	1.02	1.08	.9879	.9885	.9884
	2	115.	126.	121.	3.16	1.71	.735	.626	.672	.9980	.9985	.9985

House No.	Phase	$C^{(-1/N)}$	$D^{(-1/F)}$	A	OFFSETS E	OFFSETS C	SLOPES n	SLOPES F	SLOPES N	CORRELATION COEFFICIENTS STANDARD	CORRELATION COEFFICIENTS OFFSET	CORRELATION COEFFICIENTS EYRE
15	1	168.	171.	209.	.914	9.20	.616	.599	.456	.9943	.9944	.9940
	2	203.	530.	175.	N.A.	-9.07	.650	.340	.835	.9946	.9915	.9954
16	1	69.9	81.8	92.4	-21.3	-26.6	.510	.822	.905	.9932	.9952	.9952
	2	76.1	75.2	74.3	-1.01	-9.51	.657	.977	.991	.9913	.9917	.9929
17	1	146.	252.	150.	N.A.	-43.3	.690	.389	1.55	.9893	,9839	.9928
	2	219.	176.	183.	-26.3	-7.37	.658	1.15	.831	.9868	.9869	.9876
18	1	N.A.										
	2	119.	119.	114.	.362	-4.60	.691	.682	.804	.9967	.9967	.9968
20	1	58.5	53.3	54.3	.64	5.18	.652	.515	.546	.9981	.9986	.9986
	2	83.5	86.3	85.8	1.70	1.53	.632	.577	.583	.9986	.9988	.9988
21	1	61.5	62.9	67.1	-1.86	-7.09	.526	.558	.648	.9986	.9987	.9987
	2	84.2	87.8	84.2	2.20	-2.08	.605	.543	.610	.9966	.9967	.9966
22	1	74.3	75.0	72.6	.620	-4.69	.562	.543	.695	.9960	.9959	.9958
	2	69.9	70.4	71.9	.551	2.73	.679	.676	.604	.9961	.9962	.9964
23	1	174.	306.	252.	12.2	10.1	.575	.348	.392	.9880	.9926	.9922
	2	412.	1009.	728.	15.4	11.8	.600	.374	.429	.9967	.9981	.9980
24	1	72.6	97.7	125.	N.A.	-60.0	.521	.965	1.43	.9840	.9876	.9879
	2	137.	333.	140.	N.A.	-44.2	.614	.297	1.52	.9849	.9756	.9921
25	1	N.A.										
	2	77.6	81.7	77.2	2.25	-.946	.559	.491	.582	.9977	.9977	.9975
27	1	65.5	61.4	62.7	6.34	3.45	.559	.447	.505	.9920	.9928	.9926
	2	65.0	70.2	67.0	4.24	2.08	.623	.477	.549	.9955	.9967	.9964
28	1	41.4	44.8	43.4	6.66	6.29	.689	.391	.413	.9890	.9955	.9954
	2	53.8	54.4	55.2	-5.43	-7.49	.555	.743	.805	.9960	.9971	.9971

House No.	Phase	$C^{(-1/N)}$	$D^{(-1/F)}$	A	OFFSETS E	OFFSETS C	SLOPES n	SLOPES F	SLOPES N	CORRELATION COEFFICIENTS STANDARD	CORRELATION COEFFICIENTS OFFSET	CORRELATION COEFFICIENTS EYRE
29	1	58.5	57.4	66.5	1.24	-8.97	.548	.528	.700	.9890	.9890	.9883
	2	59.2	59.7	59.0	1.01	-.799	.587	.553	.612	.9981	.9981	.9981
30	1	N.A.										
	2	68.1	78.2	72.1	-25.4	-17.9	.511	1.20	1.01	.9931	.9975	.9976
31	1	79.7	86.1	81.7	11.0	8.06	.753	.468	.546	.9964	.9982	.9982
	2	142.	146.	150.	2.08	4.29	.640	.600	.562	.9967	.9969	.9970
32	1	51.7	44.4	44.2	8.64	8.95	.693	.490	.483	.9985	1.000	1.000
	2	82.0	90.8	89.7	5.64	5.31	.575	.435	.444	.9984	.9993	.9993
34	1	63.3	61.1	79.9	3.65	-21.1	.657	.577	1.14	.9765	.9758	.9775
	2	54.9	59.0	62.1	3.36	5.10	.723	.560	.498	.9953	.9973	.9973
35	1	N.A.										
	2	57.5	66.2	68.5	5.67	6.44	.664	.439	.412	.9923	.9973	.9973
37	1	75.9	75.7	76.9	12.7	14.4	.499	.294	.269	.9889	.9964	.9962
	2	116.	114.	113.	-1.79	-2.77	.614	.652	.675	.9973	.9974	.9974
39	1	54.1	53.4	60.8	.699	-7.12	.600	.588	.731	.9926	.9926	.9924
	2	88.4	81.3	81.6	-14.4	-15.8	.469	.833	.871	.9943	.9969	.9969
50	1	N.A.										
	2	100.	105.	99.0	.373	-6.51	.790	.682	.971	.9944	.9933	.9950

Table 2: Results for Equation 4 for Depressurized, Unsealed Tests

NOTE: The "S" terms have the 10^{-3} term omitted for tabulation. They have been multiplied by 10^{3} in the table.

HOUSE #	PHASE	R m^3/s	S $(X10^{-3})$	T	CORRELATION
1	1	-0.241	-3.05	0.175	0.9879
	2	-0.060	0.523	0.100	0.9988
2	1	-0.221	2.35	0.126	0.9906
	2	-0.216	-2.75	0.157	0.9986
3	1	-0.187	-0.828	0.152	0.9867
	2	0.115	8.83	0.0133	0.9983
4	1	NA			
	2	0.111	6.94	0.0076	0.9974
5	1	-0.058	-0.506	0.133	0.9975
	2	0.036	3.95	0.0781	0.9980
6	1	-0.257	-4.78	0.173	0.9977
	2	-0.068	1.84	0.0935	0.9957
7	1	0.070	7.65	0.0388	0.9997
	2	-0.005	4.08	0.0670	0.9958
10	1	-0.093	-0.982	0.155	0.9882
	2	0.047	7.66	0.0614	0.9981
11	1	-0.251	-5.46	0.190	0.9942
	2	-0.123	2.15	0.0836	0.9981
12	1	0.073	8.37	0.0315	0.9962
	2	0.474	17.8	0.107	0.9890
13	1	-0.345	-9.78	0.239	0.9964
	2	-0.144	-3.42	0.140	0.9931

Table 2 con't.

HOUSE #	PHASE	R m^3/s	S $(X10^{-3})$	T	CORRELATION
14	1	0.156	11.2	0.0275	0.9896
	2	-0.092	2.13	0.0737	0.9485
15	1	-0.135	-1.34	0.0956	0.0070
	2	0.073	4.85	0.0120	0.9954
16	1	0.290	8.64	0.0168	0.9952
	2	0.111	11.7	0.0134	0.9929
17	1	0.211	10.1	-0.0342	0.9927
	2	0.055	4.36	0.0148	0.9875
18	1	NA			
	2	0.005	5.04	0.0413	0.9969
20	1	-0.265	-1.72	0.176	0.9986
	2	-0.097	0.593	0.110	0.9988
21	1	0.087	3.93	0.0870	0.9988
	2	-0.079	0.510	0.109	0.9967
22	1	0.020	3.84	0.0846	0.9962
	2	-0.137	1.34	0.119	0.9964
23	1	-0.304	-7.41	0.163	0.9924
	2	-0.169	-2.78	0.0836	0.9979
24	1	0.390	11.9	-0.0232	0.9878
	2	0.285	12.2	-0.0502	0.9923
25	1	NA			
	2	-0.048	0.238	0.114	0.9977

TABLE 2 con't

HOUSE #	PHASE	R m^3/s	S ($\times 10^{-3}$)	T	CORRELATION
27	1	-0.198	-3.46	0.114	0.9928
	2	-0.169	-2.78	0.174	0.9965
28	1	-0.574	-21.7	0.365	0.9955
	2	0.150	12.0	0.0398	0.9972
29	1	-0.069	0.108	0.138	0.9890
	2	-0.043	2.31	0.117	0.9981
30	1	NA			
	2	0.271	15.1	-0.0121	0.9977
31	1	-0.369	-3.98	0.178	0.9981
	2	-0.126	-0.362	0.0927	0.9970
32	1	-0.476	-6.65	0.250	1.000
	2	-0.195	-4.98	0.166	0.9993
34	1	0.189	12.2	0.0089	0.9775
	2	-0.317	-7.33	0.213	0.9977
35	1	NA			
	2	-0.3964	-13.1	0.262	0.9977
37	1	-0.530	-15.3	0.299	0.9978
	2	-0.004	3.11	0.0627	0.9974
39	1	-0.046	3.05	0.119	0.8827
	2	0.193	8.78	0.0268	0.9969
50	1	NA			
	2	0.056	9.21	0.0085	0.9950

Table 3: Houses Tested by Nozzle, Phase 1 and 2

House and Test		Phase 1	Phase 2	Change %
2/1	n:	.483	.580	20%
	F:	.582	.498	-14%
	N:	.668	.432	-35%
2/2	n:	.793	.692	-13%
	F:	.872	.586	-33%
	N:	.585	.516	-129%
2/3	n:	.683	.727	6 %
	F:	1.06	.441	-58%
	N:	Error	.439	N.A.
17/1	n:	.732	.690	6 %
	F:	.793	Error	N.A.
	N:	1.11	1.96	76%
17/2	n:	.690	.658	-5%
	F:	.389	1.15	190%
	N:	1.55	.831	-46%
17/3	n:	.584	.723	23%
	F:	.535	.576	9%
	N:	.928	.514	-45%
22/1	n:	.529	.567	7%
	F:	.392	.819	109%
	N:	.386	.890	131%
22/2	n:	.562	.697	24%
	F:	.543	.676	24%
	N:	.695	.604	-13%
22/3	n:	.622	.580	-7%
	F:	1.03	.693	-30%
	N:	.904	Error	N.A.

Conclusions

Although the three offset equations tested in this study did produce a better data fit than the standard (CGSB)equation, the results are still highly erratic. The calculations do not seem adequate to generate a realistic offset pressure, when using real data.

In some instances, the offset pressures derived from equation 2 and 3 are in agreement in size and magnitude, as well as bearing some relationship to the wind. However, no equation, as stated, proved dependable or free of frequent anomaly.

Recommendations

1) Additional research is required to discover the actual offset pressures during airtightness tests, and the extent to which these offset pressures vary over the testing period. In addition to standard depressurization apparatus, such experimental tests should be conducted with highly sensitive pressure transducers for measuring pressure difference across the wall, and anemometers, for recording local wind conditions. The data generated could be analysed with offset equations, to determine if, and when, the equations produce accurate values for offset pressure.

2) Offset pressures, at the door fan, should be measured and recorded during all airtightness tests. The air flow channel (fan ring, or nozzle), should be completely blocked to record offsets prior to testing.

3) A standardized method for determining the on-site pressure offset should be developed for incorporating into the CGSB standard. Three possiblities are described below:

   (i) Record the indicated pressure offset from the pressure gauge prior to each test. If fluctuations are noticeable, the gauge could be sampled periodicaly over several minutes to arrive at an average value.

(ii) Use a specialized pressure transducer to measure and record the pressure difference across the door, for several minutes. This approach would permit continuous, sensitive, and accurate recordings of the pressure offset prior to each test.

(iii) On gusty days, the indicated pressure offset fluctuates. If it does decrease to zero during its cycles, then the operator could record the lowest indicated pressure at any consistent fan speed. For example, if the observed offset is 0-5Pa., the gauge for the 40Pa. reading should show 40-45 Pa., with the flow reading being taken when the gauge reading approaches 40Pa.

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Appendix A: Program Used for Calculations

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10 '
20 'PROGRAM TO ATTEMPT TO REDUCE HOME AIR LEAKAGE TEST DATA
30 '
40  DEFINT I-N
50  PRINT CHR$(26)
60  DIM P(20),Q(20),QL(20),PL(20),QB(20),W(20)
100 '    DATA FILE READER
101 DATA 'R6/2C',9
102 DATA 10,.205,15,.229,20,.271,25,.323,30,.368,35,.408
103 DATA 40,.445,45,.5,50,.520
104 'GOTO 134
105 '    FOR FURNACE DATA PROGRAM
106 DATA 'EYER',9
107 DATA 15,.199,20,.254,25,.302,30,.345,35,.385,40,.422
108 DATA 45,.457,50,.491,55,.523
110 INPUT 'FILENAME  ',F$
115 F$='B:'+F$
120 OPEN 'I',#1,F$
125 INPUT#1,T$
130 INPUT#1,N
134 'READ T$,N
135 PRINT T$,N
138 PRINT' PRESS         FLOW'
140 FOR I=1 TO N
145  INPUT#1,P(I),Q(I)
146 ' READ P(I),Q(I)
150  PRINT P(I),Q(I)
155 NEXT I
165 '    GO DO THE REST OF THE PROGRAM
188 WS=0
190 FOR I=1 TO N
193   W(I)=1:WS=WS+W(I)
195 NEXT I
200 '
210 '  CALCULATION OF STANDARD COEFF FOR  Q=C*P^N
220 FOR I=1 TO N
230   QL(I)=LOG(Q(I))
240   PL(I)=LOG(P(I))
250 NEXT I
260 '
270 'GENERATE SUMS FOR LEAST SQ CALC
280 S1=0:S2=0:S3=0:S4=0
290 FOR I=1 TO N
300   S1=S1+PL(I)
310   S2=S2+QL(I)
320   S3=S3+PL(I)*PL(I)
330   S4=S4+PL(I)*QL(I)
340 NEXT I
350 X1=S1*S1-S3*N
360 SN=(S1*S2-N*S4)/X1
370 CS=(S1*S4-S2*S3)/X1: CS=EXP(CS)
400 '
410 'CALC D, E AND F FOR A WIND OFSET MINIMZ LOG(Q)
455 E=8
460 GOSUB 4300
470  BX=1/F
480  AX=D^(-BX):CX=E
500 '
510 'CALC A, B, & C USING ONLY EYERS METHOD
520 DB=1: K=0: FM=100
525 B=1/SN
530 GOSUB 2000
540   BT=B: FT=G
550   K=K+1
555   IF ABS(G)<FM THEN FM=ABS(G): BM=B
556   B=B+DB
560   GOSUB 2000
570     IF ABS(FT-G)<1E-08 THEN DB=DB*.5: GOTO 600
582   DB=G*(B-BT)/(FT-G)
584     IF B>5 OR B<.2 THEN B=.2+4*RND:DB=.05:GOTO 530
600     IF ABS(DB)<.0005 AND ABS(G)<.00005 THEN 604
601   IF K<100 THEN 540
602 B=BM: GOSUB 2000
603 LPRINT:LPRINT:LPRINT T$;' BEST FIT OUTSIDE 0.1<B<5.0   USED B=';B:PRINT'QUIT'
604 GOSUB 3000
```

```
605 '
606 'CALC R, S &T FOR Q=R + S*P +T*SQR(P)
607 S1=0:S2=0:S3=0:S4=0:S5=0:S6=0:S7=0
608 FOR I=1 TO N
609   WP=W(I)*P(I)
610   T=W(I)*SQR(P(I))
612   S1=S1+WP
614   S2=S2+T
616   S3=S3+WP*P(I)
618   S4=S4+P(I)*T
620   S5=S5+W(I)*Q(I)
622   S6=S6+WP*Q(I)
624   S7=S7+Q(I)*T
630 NEXT I
640 X3=S1*S1-WS*S3
650 X4=S1*S2-WS*S4
660 X5=S2*S2-WS*S1
670 X6=S5*S1-WS*S6
680 X7=S5*S2-WS*S7
690 T=(X4*X6-X3*X7)/(X4*X4-X3*X5)
700 S=(X6-X4*T)/X3
710 R=(S5-S1*S-S2*T)/WS
720 PRINT"LST SQ COEF ";R;S;T
800 '
810 'SORT THE P'S
820 FOR I=1 TO N-1
830   K=0
840   FOR J=1 TO N-I
850     G=P(J+1)
860     IF P(J)<=G THEN 900
870     P(J+1)=P(J): P(J)=G
880     G=Q(J+1): Q(J+1)=Q(J): Q(J)=G
890     K=1
900   NEXT J
910   IF K=0 THEN 1000
920 NEXT I
1000 '
1010 'OUTPUT RESULTS
1020 PRINT:LPRINT
1030 PRINT:LPRINT
1035 PRINT "     TEST  ";T$
1036 LPRINT"     TEST  ";T$
1037 PRINT
1038 LPRINT
1040 PRINT "  Q(STAND) = c*P^n
1050 LPRINT"  Q(STAND) = c*P^n
1055 PRINT "  Q(OFFSET)= D(P-E)^F
1056 LPRINT"  Q(OFFSET)= D(P-E)^F      Minimize error in Ln(Q)"
1060 PRINT "  Q(EYER)  = ((P-C)/A)^N
1070 LPRINT"  Q(EYER)  = ((P-C)/A)^N   Minimize error in P"
1080 PRINT "  Q(LST SQ)= R + S*P + T*SQR(P)
1090 LPRINT"  Q(LST SQ)= R + S*P + T*SQR(P)
1100 PRINT
1110 LPRINT
1120 PRINT "STANDARD  c^(-1/n)"TAB(24)"c";TAB(35);"n"
1130 LPRINT"STANDARD  c^(-1/n)"TAB(24)"c";TAB(35);"n"
1140 PRINT  TAB(9);CS^(-1/SN);TAB(21);CS;TAB(32);SN
1150 LPRINT TAB(9);CS^(-1/SN);TAB(21);CS;TAB(32);SN
1160 PRINT "OFFSET   D^(-1/F)"TAB(24);"E"TAB(35);"F"TAB(46);"B=1/F"
1170 LPRINT"OFFSET   D^(-1/F)"TAB(24);"E"TAB(35);"F"TAB(46);"B=1/F"
1180 PRINT  TAB(9);AX;TAB(21);CX;TAB(32);1/BX;TAB(43);BX
1190 LPRINT TAB(9);AX;TAB(21);CX;TAB(32);1/BX;TAB(43);BX
1200 PRINT "EYER'S      A"TAB(24);"C";TAB(35);"N"TAB(46);"B=1/N"
1210 LPRINT"EYER'S      A"TAB(24);"C";TAB(35);"N"TAB(46);"B=1/N"
1220 PRINT  TAB(9);A;TAB(21);C;TAB(32);1/B;TAB(43);B
1230 LPRINT TAB(9);A;TAB(21);C;TAB(32);1/B;TAB(43);B
1240 PRINT "LEAST SQ    R"TAB(24);"S"TAB(35);"T"
1250 LPRINT"LEAST SQ    R"TAB(24);"S"TAB(35);"T"
1260 PRINT  TAB(9);R;TAB(20);S;TAB(33);T
1270 LPRINT TAB(9);R;TAB(20);S;TAB(33);T
1330 PRINT
1340 LPRINT
1350 PRINT "  P Q-STAND  Q-OFFST Q-EYER  Q-LSTSQ Q-MEAS ER-STND ER-OFFST ER-EYER ER-LSTSQ";
1355 LPRINT"  P Q-STNDRD Q-OFFST Q-EYER  Q-LSTSQ Q-MEAS ER-STND  ER-OFFST  ER-EYER  ER-LSTSQ"
```

```
1400 '
1410 'CALCULATE ERRORS ETC
1420 S1=0:S2=0:S3=0:S4=0:S5=0:S6=0:S7=0
1421 S8=0: S9=0: X1=0: X2=0: X3=0: X4=0: X5=0
1424 Y1=0: Y2=0: Y3=0: Y4=0
1426  H5=0: H6=0: H7=0: H8=0
1430 J=1: P(N+1)=10000
1440 FOR P=5 TO 65 STEP 5
1450   P1=P
1460   IF P=>P(J) THEN P1=P(J)
1470   X=(P1-C)/A
1480   IF X<0 THEN 1660
1490    T1=CS*P1^SN
1500    T2=ABS((P1-CX)/AX): T2=T2^(1/BX)
1510    T3=X^(1/B)
1520    T4=R+P1*S+T*SQR(P1)
1525    PRINT: LPRINT
1530    PRINT USING '### ##.#### ##.#### ##.#### ##.####';P1;T1;T2;T3;T4;
1540    LPRINT USING'### ##.#### ##.#### ##.#### ##.####';P1;T1;T2;T3;T4;
1550    IF P1<>P(J) THEN 1660
1560     E1=Q(J)-T1: E2=Q(J)-T2: E3=Q(J)-T3: E4=Q(J)-T4
1562     H1=QL(J)-LOG(T1): H2=QL(J)-LOG(T2)
1564     H3=QL(J)-LOG(T3): H4=QL(J)-LOG(T4)
1570     PRINT USING ' ##.####  #.####  #.####  #.####  #.####';Q(J);E1;E2;E3;E4;
1580     LPRINT USING' ##.####  #.####  #.####  #.####  #.####';Q(J);E1;E2;E3;E4;
1600     S1=S1+E1*E1:S2=S2+E2*E2:S3=S3+E3*E3:S4=S4+E4*E4
1605     H5=H5+H1*H1:H6=H6+H2*H2:H7=H7+H3*H3:H8=H8+H4*H4
1610     S5=S5+Q(J): S6=S6+T1: S7=S7+T2: S8=S8+T3: S9=S9+T4
1620     X1=X1+Q(J)*Q(J): X2=X2+T1*T1: X3=X3+T2*T2
1630     X4=X4+T3*T3: X5=X5+T4*T4
1640     Y1=Y1+Q(J)*T1: Y2=Y2+Q(J)*T2: Y3=Y3+Q(J)*T3: Y4=Y4+Q(J)*T4
1650    J=J+1: IF P>= P(J) THEN 1460
1660  NEXT P
1670 PRINT:LPRINT
1700 '
1710 'CORRELATION COEFF
1720 D=X1-S5*S5/N
1730 E1=Y1-S5*S6/N: E1=E1/SQR(D*(X2-S6*S6/N))
1740 E2=Y2-S5*S7/N: E2=E2/SQR(D*(X3-S7*S7/N))
1750 E3=Y3-S5*S8/N: E3=E3/SQR(D*(X4-S8*S8/N))
1760 E4=Y4-S5*S9/N: E4=E4/SQR(D*(X5-S9*S9/N))
1770 PRINT  'TOTAL SQD ERROR'TAB(43);
1771 PRINT  USING '##.##^^^^';S1;S2;S3;S4
1780 LPRINT'TOTAL SQD ERROR';TAB(44);
1781 LPRINT USING '##.##^^^^';S1;S2;S3;S4
1782 LPRINT'TOTAL SQD LOG ERROR'TAB(43);
1784 PRINT 'TOTAL SQD LOG ERROR'TAB(43);
1786 PRINT USING  '##.##^^^^';H5;H6;H7;H8
1787 LPRINT USING '##.##^^^^';H5;H6;H7;H8
1790 PRINT  'CORRELATION COEFF'TAB(45);
1791 PRINT  USING '#.#####';E1;E2;E3;E4
1800 LPRINT'CORRELATION COEFF'TAB(45);
1801 LPRINT USING ' #.####';E1;E2;E3;E4
1870 GOTO 125
1900 INPUT 'TRY SOME MORE DATA  ';Z7$
1910 Z7$=LEFT$(Z7$,1)
1920 IF Z7$='Y' THEN 125
1930 IF Z7$='N' THEN 1950
1940 GOTO 1900
1950 CLOSE#1
1960 END
```

```
2000 '
2010 'CALCULATE AYER'S B
2020 S1=0: S2=0: S3=0: S4=0
2030 FOR I=1 TO N
2040  QB(I)=Q(I)^B
2050  WQB=W(I)*QB(I)
2060  W2=WQB*QB(I)
2070  S1=S1+WQB
2080  S2=S2+WQB*QL(I)
2090  S3=S3+W2
2100  S4=S4+W2*QL(I)
2110 NEXT I
2120 X1=S1*S4-S2*S3
2130 X2=S1*S2-WS*S4
2140 X3=S1*S1-WS*S3
2150 G=0
2160 FOR I=1 TO N
2170   G=G+P(I)*W(I)*(X1+QB(I)*(X2-QL(I)*X3))
2180 NEXT I
2185 PRINT B;G;X1
2190 RETURN
2500 '
2510 'CALCULATE  B  BY HILL CLIMBING
2520 S1=0: S2=0: S3=0: S4=0
2530 FOR I= 1 TO N
2540   QB(I)=Q(I)^B
2550   WQB=W(I)*QB(I)
2560   S1=S1+WQB
2570   S3=S3+WQB*QB(I)
2610 NEXT I
2620 X3=S1*S1-WS*S3
2630 GOSUB 3000
2640 '
2650 G=0:B1=1/B
2670 FOR I=1 TO N
2675   X=(P(I)-C)/A
2676   IF X<=0 THEN G=100: GOTO 2710
2680   EI=Q(I)-((P(I)-C)/A)^B1
2690   G=G+EI*EI
2700 NEXT I
2710 PRINT "B=";B;"A=";A;"C=";C;"G=";G
2720 RETURN
3000 '
3010 'CALCULATE EYERS A AND C
3020 A=0: C=0
3030 FOR I=1 TO N
3040   A=A+P(I)*W(I)*(S1-QB(I)*WS)
3050   C=C+P(I)*W(I)*(-S3+QB(I)*S1)
3060 NEXT I
3070 A=A/X3: C=C/X3
3080 RETURN
```

```
4000 '
4010 'LEAST SQUARES FIT FOR  Q=D(P-E)^F
4020 S1=0:S2=0:S3=0:S4=0:S5=0:S6=0:S7=0
4030 FOR I=1 TO N
4040   P1=1/(P(I)-E)
4050   P2=LOG(P(I)-E)
4060   S1=S1+QL(I)
4070   S2=S2+P2
4080   S3=S3+P2*QL(I)
4090   S4=S4+P2*P2
4100   S5=S5+QL(I)*P1
4110   S6=S6+P1
4120   S7=S7+P2*P1
4130 NEXT I
4140 X1=S2*S2-S4*N
4150 X2=S3*S2-S1*S4
4160 X3=S1*S2-S3*N
4170 G=-S5*X1+S6*X2+S7*X3
4180 PRINT "E=";E;"G=";G
4190 RETURN
4200 '
4210 ' CALC D AND F FOR Q=D(P-E)^F
4220 D=X2/X1: D=EXP(D)
4230 F=X3/X1
4235 PRINT"E=";E;" D=";D;" F=";F
4240 RETURN
4300 '
4310 'ITERATION FOR Q=D(P-E)^F
4320 K=0
4325 DB=-.2: PRINT"START "
4330 GOSUB 4000
4340   BT=E:FT=G
4350   E=E+DB:K=K+1
4352  IF E<-30 THEN E=29
4353  IF E>P(1) THEN E=P(1)-RND: GOTO 4325
4354  IF E>30 THEN E=-10+50*RND: GOTO 4325
4355   GOSUB 4000
4360   IF ABS(FT-G)<1E-08 THEN DB=.5*DB: GOTO 4340
4380     DB=G*(E-BT)/(FT-G)
4390     IF ABS(DB)<.002 THEN 4420
4406     IF K>100 THEN E=0:GOTO 4412
4410   GOTO 4340
4412   LPRINT T$;" MIN OFFSET OUTSIDE -30<E<30 USED E=0":PRINT"QUIT"
4420 GOSUB 4200
4450 RETURN
```

Appendix B: A Sample of 20 Calculations

Twenty tests, from Phase 2 testing were selected, as they generally illustrate the trends described in the report.

The Apple Hill airtightness tests differ slightly for the CGSB standards. Both pressurized and depressurized tests are performed when the house is unsealed. In houses with low neutral pressure planes, the pressurized test more accurately reflects the leakage.

CGSB standards call for sealing the furnace and hot water heater flues. Because of the enclosed furnace rooms in Apple Hill, the flues were left open in the tests labelled "CGSB". All intentional openings were sealed in the tests labelled "sealed".

A note on the nomenclature:

e.g. R14/2A

R: means the test has been programmed for this report.

14: indicates the house code number. This code number is consistent for all Apple Hill testing

2: this indicates the type of test
- 1 - Pressurized, CGSB (unsealed)
- 2 - Depressurized, CGSB (unsealed)
- 3 - Depressurized, sealed

A: indicates Phase 2 Tests
- A - Phase 2
- C - Phase 1
- B,C,E, etc. - a retest with different data

TEST R4/1A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	52.5848	.038969	.735188	
OFFSET	D^(-1/F)	E	F	B=1/F
	79.8991	-4.6727	.901791	1.1089
EYER'S	A	C	N	B=1/N
	81.6333	-12.3651	1.16279	.859999
LEAST SQ	R	S	T	
	.131657	.0141023	-.0159225	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1272	0.1490	0.1553	0.1666					
10	0.2118	0.2169	0.2219	0.2223	0.2180	0.0042	-.0039	-.0089	-.0043
15	0.2853	0.2826	0.2806	0.2815	0.2780	-.0073	-.0046	-.0026	-.0035
20	0.3525	0.3466	0.3410	0.3425	0.3660	0.0135	0.0194	0.0250	0.0235
25	0.4154	0.4093	0.4030	0.4046	0.4120	-.0034	0.0027	0.0090	0.0074
30	0.4750	0.4710	0.4664	0.4675	0.4540	-.0210	-.0170	-.0124	-.0135
35	0.5320	0.5319	0.5310	0.5310	0.5170	-.0150	-.0149	-.0140	-.0140
40	0.5869	0.5920	0.5967	0.5950	0.5820	-.0049	-.0100	-.0147	-.0130
45	0.6399	0.6514	0.6635	0.6594	0.6790	0.0391	0.0276	0.0155	0.0196
50	0.6915	0.7102	0.7312	0.7242					
55	0.7417	0.7686	0.7998	0.7892					
60	0.7907	0.8264	0.8692	0.8545					
65	0.8386	0.8838	0.9395	0.9199					
TOTAL SQD ERROR						2.46E-03	1.78E-03	1.85E-03	1.85E-03
TOTAL SQD LOG ERROR						8.97E-03	7.47E-03	8.89E-03	8.65E-03
CORRELATION COEFF						0.9928	0.9947	0.9954	0.9952

TEST R4/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	143.897	.0424751	.635696	
OFFSET	D^(-1/F)	E	F	B=1/F
	131.109	-15.6362	.964857	1.03642
EYER'S	A	C	N	B=1/N
	130.264	-12.9153	.915764	1.09196
LEAST SQ	R	S	T	
	.111605	6.94758E-03	7.62631E-03	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1182	0.1680	0.1625	0.1634					
10	0.1836	0.2071	0.2036	0.2052					
15	0.2376	0.2459	0.2440	0.2454	0.2480	0.0104	0.0021	0.0040	0.0026
20	0.2852	0.2845	0.2837	0.2847	0.2770	-.0082	-.0075	-.0067	-.0077
25	0.3287	0.3230	0.3230	0.3234	0.3350	0.0063	0.0120	0.0120	0.0116
30	0.3691	0.3612	0.3617	0.3618	0.3500	-.0191	-.0112	-.0117	-.0118
35	0.4071	0.3993	0.4002	0.3999	0.4040	-.0031	0.0047	0.0038	0.0041
40	0.4432	0.4373	0.4382	0.4377	0.4340	-.0092	-.0033	-.0042	-.0037
45	0.4776	0.4752	0.4760	0.4754	0.4880	0.0104	0.0128	0.0120	0.0126
50	0.5107	0.5129	0.5135	0.5129	0.5040	-.0067	-.0089	-.0095	-.0089
55	0.5426	0.5506	0.5508	0.5503	0.5520	0.0094	0.0014	0.0012	0.0017
60	0.5735	0.5882	0.5878	0.5875	0.5870	0.0135	-.0012	-.0008	-.0005
65	0.6034	0.6256	0.6246	0.6247					
TOTAL SQD ERROR						1.10E-03	6.12E-04	6.13E-04	6.11E-04
TOTAL SQD LOG ERROR						7.86E-03	4.35E-03	4.43E-03	4.38E-03
CORRELATION COEFF						0.9957	0.9974	0.9974	0.9974

TEST R4/3A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	260.406	.0298548	.631294	
OFFSET	D^(-1/F)	E	F	B=1/F
	201.114	-18.412	.969105	1.031788
EYER'S	A	C	N	B=1/N
	211.252	-11.0572	.84052	1.18974
LEAST SQ	R	S	T	
	.0668613	4.04817E-03	.0117004	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.0825	0.1244	0.1146	0.1133					
10	0.1277	0.1501	0.1440	0.1443					
15	0.1650	0.1756	0.1722	0.1729					
20	0.1979	0.2010	0.1996	0.2002	0.2020	0.0041	0.0010	0.0024	0.0018
25	0.2279	0.2243	0.2243	0.2246					
30	0.2556	0.2515	0.2524	0.2524	0.2480	-.0076	-.0035	-.0044	-.0044
35	0.2817	0.2767	0.2780	0.2778					
40	0.3065	0.3018	0.3031	0.3028	0.3030	-.0035	0.0012	-.0001	0.0002
45	0.3301	0.3268	0.3279	0.3275					
50	0.3528	0.3517	0.3523	0.3520	0.3570	0.0042	0.0053	0.0047	0.0050
55	0.3747	0.3766	0.3764	0.3763	0.3770	0.0023	0.0004	0.0006	0.0007
60	0.3959	0.4014	0.4002	0.4004	0.3970	0.0011	-.0044	-.0032	-.0034
65	0.4164	0.4262	0.4237	0.4243					
TOTAL SQD ERROR						1.10E-04	6.29E-05	5.77E-05	5.97E-05
TOTAL SQD LOG ERROR						1.65E-03	5.90E-04	6.92E-04	6.67E-04
CORRELATION COEFF						0.9982	0.9989	0.9990	0.9990

TEST R5/1A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	60.4395	.0605464	.683713	
OFFSET	D^(-1/F)	E	F	B=1/F
	64.0832	4.35767	.519187	1.92609
EYER'S	A	C	N	B=1/N
	61.7705	2.39371	.592875	1.6867
LEAST SQ	R	S	T	
	-.162458	1.86206E-04	.141989	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1820	0.0917	0.1531	0.1560					
10	0.2923	0.2832	0.2889	0.2884	0.2820	-.0103	-.0012	-.0069	-.0064
15	0.3857	0.3937	0.3898	0.3903	0.3980	0.0123	0.0043	0.0082	0.0077
20	0.4695	0.4809	0.4751	0.4763	0.4920	0.0225	0.0111	0.0169	0.0157
25	0.5469	0.5554	0.5510	0.5521	0.5330	-.0139	-.0224	-.0180	-.0191
30	0.6195	0.6215	0.6203	0.6208	0.6160	-.0035	-.0055	-.0043	-.0048
35	0.6883	0.6818	0.6847	0.6841	0.6880	-.0003	0.0062	0.0033	0.0039
40	0.7541	0.7374	0.7451	0.7430	0.7460	-.0081	0.0086	0.0009	0.0030
45	0.8174	0.7894	0.8024	0.7984					
50	0.8784	0.8385	0.8569	0.8509					
55	0.9376	0.8850	0.9092	0.9008					
60	0.9950	0.9293	0.9595	0.9486					
65	1.0510	0.9718	1.0080	0.9944					
TOTAL SQD ERROR						1.04E-03	7.86E-04	7.56E-04	7.63E-04
TOTAL SQD LOG ERROR						5.28E-03	2.64E-03	3.42E-03	3.36E-03
CORRELATION COEFF						0.9969	0.9975	0.9976	0.9976

TEST R5/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	83.5828	.0546806	.656654	
OFFSET	D^(-1/F)	E	F	B=1/F
	87.6806	2.76063	.568274	1.75972
EYER'S	A	C	N	B=1/N
	83.5473	-.713787	.674237	1.48316
LEAST SQ	R	S	T	
	-.0368162	3.95506E-03	.0781068	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1573	0.1244	0.1639	0.1576					
10	0.2480	0.2424	0.2504	0.2497	0.2390	-.0090	-.0034	-.0114	-.0107
15	0.3237	0.3266	0.3241	0.3250	0.3380	0.0143	0.0114	0.0139	0.0130
20	0.3910	0.3968	0.3905	0.3916	0.4070	0.0160	0.0102	0.0165	0.0154
25	0.4527	0.4586	0.4513	0.4526	0.4430	-.0097	-.0156	-.0083	-.0096
30	0.5103	0.5146	0.5093	0.5096	0.4980	-.0123	-.0166	-.0113	-.0116
35	0.5646	0.5663	0.5638	0.5637	0.5610	-.0036	-.0053	-.0029	-.0027
40	0.6164	0.6147	0.6159	0.6154	0.6180	0.0016	0.0033	0.0021	0.0026
45	0.6659	0.6603	0.6659	0.6651	0.6650	-.0009	0.0047	-.0009	-.0001
50	0.7136	0.7037	0.7142	0.7132	0.7170	0.0034	0.0133	0.0028	0.0038
55	0.7597	0.7451	0.7609	0.7600					
60	0.8044	0.7848	0.8063	0.8055					
65	0.8478	0.8230	0.8505	0.8500					

TOTAL SQD ERROR 9.15E-04 1.00E-03 9.50E-04 9.77E-04
TOTAL SQD LOG ERROR 5.99E-03 4.81E-03 5.57E-03 6.02E-03
CORRELATION COEFF 0.9980 0.9975 0.9979 0.9980

R5/3A BEST FIT OUTSIDE 0.1<B<5.0 USED B= 4.96375

TEST R5/3A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	179.354	.0367448	.64301	
OFFSET	D^(-1/F)	E	F	B=1/F
	153.43	-24.3467	1.12958	.885282
EYER'S	A	C	N	B=1/N
	987.873	26.8815	.20146	4.96375
LEAST SQ	R	S	T	
	.119835	6.39232E-03	2.32214E-03	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ

TOTAL SQD ERROR 0.00E+00 0.00E+00 0.00E+00 0.00E+00
TOTAL SQD LOG ERROR 0.00E+00 0.00E+00 0.00E+00 0.00E+00
CORRELATION COEFF 1.70141E+38 1.70141E+38 1.70141E+38 1.70141E+38

TEST R6/1A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	83.8871	.0684752	.605328	
OFFSET	D^(-1/F)	E	F	B=1/F
	80.5457	-3.01985	.700188	1.42819
EYER'S	A	C	N	B=1/N
	79.513	-7.02328	.820296	1.21909
LEAST SQ	R	S	T	
	.0783875	8.19181E-03	.0332553	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1814	0.1988	0.2123	0.2051					
10	0.2760	0.2791	0.2824	0.2816	0.2770	0.0010	-.0021	-.0054	-.0046
15	0.3527	0.3505	0.3489	0.3498	0.3570	0.0043	0.0065	0.0081	0.0072
20	0.4198	0.4160	0.4126	0.4138	0.4160	-.0038	-.0000	0.0034	0.0022
25	0.4806	0.4774	0.4743	0.4750	0.4780	-.0026	0.0006	0.0037	0.0030
30	0.5366	0.5356	0.5342	0.5342	0.5190	-.0176	-.0166	-.0152	-.0152
35	0.5891	0.5912	0.5927	0.5920	0.5960	0.0069	0.0048	0.0033	0.0040
40	0.6387	0.6446	0.6499	0.6486	0.6520	0.0133	0.0074	0.0021	0.0034
45	0.6859	0.6962	0.7061	0.7043					
50	0.7311	0.7462	0.7613	0.7592					
55	0.7745	0.7948	0.8157	0.8134					
60	0.8164	0.8421	0.8692	0.8670					
65	0.8569	0.8884	0.9221	0.9201					
TOTAL SQD ERROR							5.7E-04	4.0E-04	3.6E-04	3.4E-04
TOTAL SQD LOG ERROR							1.9E-03	1.5E-03	1.9E-03	1.9E-03
CORRELATION COEFF							0.9973	0.9981	0.9982	0.9983

TEST R6/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	89.3955	.0568299	.638248	
OFFSET	D^(-1/F)	E	F	B=1/F
	96.1131	3.20734	.537871	1.85918
EYER'S	A	C	N	B=1/N
	90.2247	.590552	.620243	1.61227
LEAST SQ	R	S	T	
	-.0680737	.0018481	.0935469	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1587	0.1175	0.1538	0.1503					
10	0.2471	0.2405	0.2461	0.2462	0.2370	-.0101	-.0035	-.0091	-.0092
15	0.3200	0.3235	0.3205	0.3220	0.3420	0.0220	0.0185	0.0215	0.0200
20	0.3846	0.3913	0.3856	0.3872	0.3770	-.0076	-.0143	-.0086	-.0102
25	0.4434	0.4502	0.4445	0.4459	0.4510	0.0076	0.0008	0.0065	0.0051
30	0.4981	0.5030	0.4989	0.4997	0.5040	0.0059	0.0010	0.0051	0.0043
35	0.5496	0.5515	0.5500	0.5500	0.5240	-.0256	-.0275	-.0260	-.0260
40	0.5985	0.5966	0.5983	0.5975	0.6080	0.0095	0.0114	0.0097	0.0105
45	0.6453	0.6389	0.6443	0.6426	0.6520	0.0067	0.0131	0.0077	0.0094
50	0.6901	0.6790	0.6883	0.6858	0.6820	-.0081	0.0030	-.0063	-.0038
55	0.7334	0.7171	0.7307	0.7273					
60	0.7753	0.7535	0.7717	0.7674					
65	0.8160	0.7885	0.8114	0.8063					
TOTAL SQD ERROR							1.5E-03	1.6E-03	1.5E-03	1.5E-03
TOTAL SQD LOG ERROR							9.7E-03	8.0E-03	9.2E-03	8.9E-03
CORRELATION COEFF							0.9956	0.9965	0.9957	0.9959

TEST R6/3A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	C	n	
	192.679	.0335103	.645483	
OFFSET	D^(-1/F)	E	F	B=1/F
	178.463	-4.94791	.739033	1.35312
EYER'S	A	C	N	B=1/N
	182.004	-2.82234	.703066	1.42234
LEAST SQ	R	S	T	
	4.70935E-03	2.88306E-03	.0381553	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.0947	0.1184	0.1094	0.1044					
10	0.1481	0.1600	0.1549	0.1542					
15	0.1925	0.1980	0.1952	0.1957					
20	0.2317	0.2336	0.2323	0.2330	0.2370	0.0053	0.0034	0.0047	0.0040
25	0.2676	0.2674	0.2670	0.2676	0.2580	-.0096	-.0094	-.0090	-.0096
30	0.3010	0.2997	0.2999	0.3002	0.3030	0.0020	0.0033	0.0031	0.0028
35	0.3325	0.3308	0.3313	0.3313	0.3350	0.0025	0.0042	0.0037	0.0037
40	0.3625	0.3609	0.3615	0.3613	0.3640	0.0015	0.0031	0.0024	0.0027
45	0.3911	0.3902	0.3908	0.3904	0.3910	-.0001	0.0008	0.0002	0.0006
50	0.4186	0.4187	0.4191	0.4187	0.4100	-.0086	-.0087	-.0091	-.0087
55	0.4452	0.4465	0.4466	0.4462	0.4510	0.0058	0.0045	0.0044	0.0048
60	0.4709	0.4738	0.4734	0.4732	0.4730	0.0021	-.0008	-.0004	-.0002
65	0.4959	0.5005	0.4996	0.4997					
TOTAL SQD ERROR							2.45E-04	2.74E-04	2.73E-04	2.71E-04
TOTAL SQD LOG ERROR							2.59E-03	2.38E-03	2.43E-03	2.41E-03
CORRELATION COEFF							0.9977	0.9978	0.9978	0.9978

TEST R7/1A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	C	n	
	77.6485	.0485191	.695235	
OFFSET	D^(-1/F)	E	F	B=1/F
	82.1104	3.59505	.572011	1.74822
EYER'S	A	C	N	B=1/N
	78.1828	-.0463782	.691482	1.44617
LEAST SQ	R	S	T	
	-.0667931	4.02743E-03	.0845489	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1485	0.0976	0.1503	0.1424					
10	0.2405	0.2324	0.2420	0.2408	0.2290	-.0115	-.0034	-.0130	-.0118
15	0.3188	0.3233	0.3200	0.3211	0.3380	0.0192	0.0147	0.0180	0.0169
20	0.3894	0.3980	0.3902	0.3919	0.4010	0.0116	0.0030	0.0108	0.0091
25	0.4548	0.4635	0.4552	0.4566	0.4550	0.0002	-.0085	-.0002	-.0016
30	0.5162	0.5226	0.5162	0.5171	0.4980	-.0182	-.0246	-.0182	-.0191
35	0.5747	0.5771	0.5742	0.5744	0.5790	0.0044	0.0019	0.0048	0.0046
40	0.6306	0.6280	0.6296	0.6290	0.6180	-.0126	-.0100	-.0116	-.0110
45	0.6844	0.6760	0.6830	0.6816	0.6960	0.0116	0.0200	0.0130	0.0144
50	0.7364	0.7215	0.7346	0.7324	0.7310	-.0054	0.0095	-.0036	-.0014
55	0.7868	0.7650	0.7846	0.7817					
60	0.8359	0.8067	0.8332	0.8298					
65	0.8837	0.8469	0.8806	0.8766					
TOTAL SQD ERROR							1.31E-03	1.51E-03	1.29E-03	1.27E-03
TOTAL SQD LOG ERROR							8.76E-03	6.21E-03	8.68E-03	7.67E-03
CORRELATION COEFF							0.9971	0.9967	0.9971	0.9972

TEST R7/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	93.7645	.0564293	.633099	
OFFSET	D^(-1/F)	E	F	B=1/F
	99.1124	4.33057	.527337	1.89632
EYER'S	A	C	N	B=1/N
	92.5962	-3.64307	.718128	1.39251
LEAST SQ	R	S	T	
	-5.02035E-03	4.08643E-03	.0670281	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1563	0.0717	0.1821	0.1633					
10	0.2424	0.2212	0.2529	0.2478					
15	0.3134	0.3087	0.3163	0.3159	0.3040	-.0094	-.0047	-.0123	-.0119
20	0.3760	0.3781	0.3752	0.3765	0.3930	0.0170	0.0149	0.0178	0.0165
25	0.4331	0.4375	0.4306	0.4323	0.4330	0.0029	-.0015	0.0024	0.0007
30	0.4860	0.4905	0.4834	0.4847	0.4910	0.0050	0.0005	0.0076	0.0063
35	0.5359	0.5387	0.5339	0.5345	0.5210	-.0149	-.0177	-.0129	-.0135
40	0.5831	0.5834	0.5827	0.5824	0.5770	-.0061	-.0064	-.0057	-.0054
45	0.6283	0.6252	0.6299	0.6285	0.6200	-.0083	-.0052	-.0099	-.0085
50	0.6716	0.6646	0.6757	0.6733	0.6860	0.0144	0.0214	0.0103	0.0127
55	0.7134	0.7020	0.7204	0.7168					
60	0.7538	0.7377	0.7640	0.7594					
65	0.7930	0.7720	0.8066	0.8010					
TOTAL SQD ERROR						9.45E-04	1.09E-03	9.59E-04	9.15E-04
TOTAL SQD LOG ERROR						4.56E-03	4.06E-03	5.31E-03	4.84E-03
CORRELATION COEFF						0.9957	0.9950	0.9956	0.9953

TEST R7/3A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	152.612	.0266059	.7213	
OFFSET	D^(-1/F)	E	F	B=1/F
	167.303	4.90281	.614335	1.62778
EYER'S	A	C	N	B=1/N
	156.519	1.6486	.685347	1.45912
LEAST SQ	R	S	T	
	-.0604358	.0019872	.0605259	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.0849	0.0103	0.0718	0.0648					
10	0.1400	0.1171	0.1342	0.1308					
15	0.1876	0.1782	0.1851	0.1838					
20	0.2309	0.2282	0.2302	0.2300	0.2270	-.0039	-.0012	-.0032	-.0030
25	0.2712	0.2720	0.2715	0.2719					
30	0.3093	0.3118	0.3101	0.3107	0.3210	0.0117	0.0092	0.0109	0.0103
35	0.3457	0.3486	0.3466	0.3472	0.3440	-.0017	-.0046	-.0026	-.0032
40	0.3807	0.3831	0.3814	0.3819	0.3790	-.0017	-.0041	-.0024	-.0029
45	0.4144	0.4158	0.4148	0.4150	0.4120	-.0024	-.0038	-.0028	-.0030
50	0.4471	0.4469	0.4471	0.4469	0.4420	-.0051	-.0049	-.0051	-.0049
55	0.4790	0.4767	0.4782	0.4777	0.4860	0.0070	0.0093	0.0078	0.0083
60	0.5100	0.5054	0.5085	0.5076	0.5060	-.0040	0.0006	-.0025	-.0016
65	0.5403	0.5331	0.5380	0.5367					
TOTAL SQD ERROR						2.55E-04	2.49E-04	2.42E-04	2.38E-04
TOTAL SQD LOG ERROR						2.15E-03	1.75E-03	1.94E-03	1.86E-03
CORRELATION COEFF						0.9979	0.9979	0.9980	0.9981

TEST R10/1A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	58.4037	.0783011	.626249	
OFFSET	D^(-1/F)	E	F	B=1/F
	58.6242	.575223	.60587	1.65052
EYER'S	A	C	N	B=1/N
	58.3375	1.17509	.590604	1.69312
LEAST SQ	R	S	T	
	-.152819	-1.50839E-03	.15636	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.2145	0.2090	0.2000	0.1893					
10	0.3311	0.3304	0.3278	0.3265	0.3320	0.0009	0.0016	0.0042	0.0055
15	0.4269	0.4276	0.4273	0.4301	0.4220	-.0049	-.0056	-.0053	-.0081
20	0.5111	0.5121	0.5127	0.5163	0.5120	0.0009	-.0001	-.0007	-.0043
25	0.5878	0.5893	0.5893	0.5913	0.5870	-.0008	-.0023	-.0023	-.0043
30	0.6589	0.6586	0.6584	0.6583	0.6850	0.0261	0.0264	0.0266	0.0267
35	0.7257	0.7243	0.7248	0.7194	0.7040	-.0217	-.0203	-.0208	-.0154
40	0.7890	0.7863	0.7862	0.7758					
45	0.8494	0.8453	0.8446	0.8282					
50	0.9073	0.9017	0.9002	0.8774					
55	0.9631	0.9560	0.9536	0.9238					
60	1.0170	1.0083	1.0049	0.9678					
65	1.0693	1.0588	1.0545	1.0097					
TOTAL SQD ERROR						1.15E-03	1.11E-03	1.11E-03	1.19E-03
TOTAL SQD LOG ERROR						2.57E-03	2.55E-03	2.50E-03	2.81E-03
CORRELATION COEFF						0.9946	0.9947	0.9948	0.9950

TEST R10/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	66.3551	.0770454	.611048	
OFFSET	D^(-1/F)	E	F	B=1/F
	65.9767	-4.57968	.755297	1.32398
EYER'S	A	C	N	B=1/N
	65.4085	-3.25499	.719018	1.39079
LEAST SQ	R	S	T	
	.0474289	7.66302E-03	.0614742	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.2060	0.2328	0.2258	0.2232					
10	0.3146	0.3197	0.3173	0.3185	0.3210	0.0064	0.0013	0.0037	0.0025
15	0.4031	0.3995	0.3995	0.4005	0.3930	-.0101	-.0065	-.0065	-.0075
20	0.4806	0.4744	0.4754	0.4756	0.4870	0.0064	0.0126	0.0116	0.0114
25	0.5508	0.5456	0.5469	0.5464	0.5320	-.0188	-.0136	-.0149	-.0144
30	0.6157	0.6139	0.6148	0.6140	0.6200	0.0043	0.0061	0.0052	0.0060
35	0.6765	0.6798	0.6800	0.6793	0.6870	0.0105	0.0072	0.0070	0.0077
40	0.7340	0.7437	0.7428	0.7427	0.7370	0.0030	-.0067	-.0058	-.0057
45	0.7888	0.8059	0.8036	0.8046					
50	0.8412	0.8666	0.8626	0.8653					
55	0.8916	0.9259	0.9201	0.9248					
60	0.9403	0.9840	0.9762	0.9834					
65	0.9875	1.0410	1.0311	1.0411					
TOTAL SQD ERROR						6.74E-04	5.22E-04	5.20E-04	5.24E-04
TOTAL SQD LOG ERROR						2.73E-03	1.90E-03	1.87E-03	1.87E-03
CORRELATION COEFF						0.9977	0.9981	0.9981	0.9981

TEST R10/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	155.504	.0330048	.675912	
OFFSET	D^(-1/F)	E	F	B=1/F
	155.655	.068212	.67454	1.48249
EYER'S	A	C	N	B=1/N
	154.223	-.12014	.681671	1.46698
LEAST SQ	R	S	T	
	-.0590109	1.96286E-03	.0601529	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.0950	0.0974	0.0982	0.0953					
10	0.1565	0.1563	0.1582	0.1598					
15	0.2058	0.2057	0.2053	0.2034					
20	0.2500	0.2500	0.2495	0.2493	0.2490	-.0010	-.0010	-.0005	-.0013
25	0.2907	0.2907	0.2902	0.2908	0.2940	0.0053	0.0053	0.0068	0.0068
30	0.3288	0.3289	0.3285	0.3293	0.3210	-.0078	-.0078	-.0075	-.0088
35	0.3649	0.3650	0.3647	0.3656	0.3660	0.0011	0.0010	0.0013	0.0004
40	0.3994	0.3994	0.3994	0.3999	0.4060	0.0066	0.0066	0.0066	0.0061
45	0.4325	0.4325	0.4327	0.4328	0.4250	-.0075	-.0077	-.0077	-.0088
50	0.4644	0.4644	0.4648	0.4645	0.4630	0.0006	0.0005	0.0002	0.0005
55	0.4953	0.4953	0.4959	0.4951	0.5070	0.0117	0.0117	0.0111	0.0119
60	0.5254	0.5253	0.5261	0.5247	0.5170	-.0084	-.0093	-.0091	-.0077
65	0.5546	0.5545	0.5556	0.5535					
TOTAL SQD ERROR							3.97E-04	3.97E-04	4.00E-04
TOTAL SQD LOG ERROR							2.31E-03	2.30E-03	2.32E-03
CORRELATION COEFF							0.9972	0.9972	0.9972

TEST R11/1A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	112.927	.0555916	.611356	
OFFSET	D^(-1/F)	E	F	B=1/F
	141.796	4.97514	.457982	2.18349
EYER'S	A	C	N	B=1/N
	118.291	.911617	.575879	1.73648
LEAST SQ	R	S	T	
	-.0775082	-1.0242E-05	.0958939	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1487	0.0190	0.1440	0.1369					
10	0.2272	0.2166	0.2282	0.2256	0.2140	-.0132	-.0026	-.0142	-.0116
15	0.2911	0.2972	0.2937	0.2937	0.3110	0.0199	0.0138	0.0173	0.0173
20	0.3471	0.3577	0.3498	0.3511	0.3560	0.0089	-.0017	0.0062	0.0049
25	0.3978	0.4080	0.3999	0.4017	0.3960	-.0018	-.0120	-.0039	-.0057
30	0.4447	0.4519	0.4458	0.4474	0.4500	0.0053	-.0019	0.0042	0.0026
35	0.4886	0.4912	0.4885	0.4894	0.4820	-.0066	-.0092	-.0065	-.0074
40	0.5302	0.5271	0.5285	0.5286	0.5230	-.0072	-.0041	-.0055	-.0056
45	0.5698	0.5603	0.5665	0.5653	0.5600	-.0098	-.0003	-.0065	-.0053
50	0.6077	0.5913	0.6026	0.6001	0.6110	0.0033	0.0197	0.0084	0.0109
55	0.6442	0.6205	0.6372	0.6331					
60	0.6793	0.6482	0.6705	0.6647					
65	0.7134	0.6746	0.7026	0.6949					
TOTAL SQD ERROR							8.84E-04	8.36E-04	7.57E-04
TOTAL SQD LOG ERROR							9.46E-03	4.63E-03	8.49E-03
CORRELATION COEFF							0.9968	0.9988	0.9971

TEST R11/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	104.58	.0312745	.744473	
OFFSET	D^(-1/F)	E	F	B=1/F
	113.112	5.81134	.589903	1.69519
EYER'S	A	C	N	B=1/N
	107.64	2.6644	.672076	1.48793
LEAST SQ	R	S	T	
	-.123635	2.15669E-03	.0836037	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.1040	0.0543	0.0762	0.0741					
10	0.1742	0.1431	0.1644	0.1623					
15	0.2356	0.2274	0.2332	0.2325	0.2260	-.0096	-.0014	-.0072	-.0065
20	0.2918	0.2939	0.2931	0.2934	0.2940	0.0022	0.0001	0.0009	0.0006
25	0.3446	0.3512	0.3475	0.3483	0.3640	0.0194	0.0128	0.0165	0.0157
30	0.3947	0.4026	0.3981	0.3990	0.4040	0.0093	0.0014	0.0059	0.0050
35	0.4427	0.4497	0.4456	0.4465	0.4340	-.0087	-.0157	-.0116	-.0125
40	0.4890	0.4937	0.4908	0.4914	0.4830	-.0060	-.0107	-.0078	-.0084
45	0.5339	0.5361	0.5341	0.5342	0.5420	0.0082	0.0059	0.0078	0.0078
50	0.5773	0.5744	0.5757	0.5754	0.5700	-.0073	-.0044	-.0057	-.0054
55	0.6198	0.6119	0.6159	0.6150	0.6120	-.0078	0.0001	-.0039	-.0030
60	0.6612	0.6478	0.6549	0.6534	0.6600	-.0012	0.0122	0.0051	0.0066
65	0.7018	0.6825	0.6927	0.6906					
TOTAL SQD ERROR						8.54E-04	7.44E-04	6.78E-04	6.82E-04
TOTAL SQD LOG ERROR						6.43E-03	3.66E-03	4.73E-03	4.43E-03
CORRELATION COEFF						0.9977	0.9979	0.9981	0.9981

TEST R11/3A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	200.063	.0228159	.713448	
OFFSET	D^(-1/F)	E	F	B=1/F
	195.201	-2.13714	.749695	1.33388
EYER'S	A	C	N	B=1/N
	230.852	7.75563	.581306	1.72026
LEAST SQ	R	S	T	
	-.140177	1.1789E-05	.0724299	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
10	0.1179	0.1246	0.0677	0.0890					
15	0.1575	0.1614	0.1337	0.1405					
20	0.1934	0.1956	0.1814	0.1840					
25	0.2268	0.2278	0.2213	0.2223					
30	0.2583	0.2586	0.2566	0.2569	0.2580	-.0003	-.0006	0.0014	0.0011
35	0.2883	0.2882	0.2887	0.2887	0.2860	-.0023	-.0022	-.0027	-.0027
40	0.3171	0.3168	0.3185	0.3184	0.3190	0.0019	0.0022	0.0005	0.0006
45	0.3449	0.3446	0.3463	0.3462	0.3490	0.0041	0.0044	0.0027	0.0028
50	0.3718	0.3717	0.3726	0.3726	0.3710	-.0008	-.0007	-.0016	-.0016
55	0.3980	0.3981	0.3976	0.3976	0.3970	-.0010	-.0011	-.0006	-.0006
60	0.4235	0.4239	0.4216	0.4216	0.4220	-.0015	-.0019	0.0004	0.0004
65	0.4484	0.4493	0.4446	0.4445					
TOTAL SQD ERROR						2.96E-05	3.45E-05	2.01E-05	1.95E-05
TOTAL SQD LOG ERROR						2.63E-04	3.02E-04	2.05E-04	1.98E-04
CORRELATION COEFF						0.9993	0.9992	0.9995	0.9995

```
 TEST  R12/1A

 Q(STAND) = c*P^n
 Q(OFFSET)= D(P-E)^F      Minimize error in Ln(Q)
 Q(EYER)  = ((P-C)/A)^N   Minimize error in P
 Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD  c^(-1/n)      c          n
          97.274        .0608321   .611604
OFFSET    D^(-1/F)      E          F          B=1/F
          114.103       7.38503    .433715    2.30566
EYER'S    A             C          N          B=1/N
          107.366       6.09455    .470296    2.12632
LEAST SQ  R             S          T
          -.232156      -4.74853E-03  .158754

  P Q-STNDRD Q-OFFST Q-EYER  Q-LSTSQ Q-MEAS ER-STND  ER-OFFST  ER-EYER  ER-LSTSQ

 10  0.2487  0.1944  0.2105  0.2224
 15  0.3187  0.3091  0.3101  0.3115  0.3070  -.0117   -.0021   -.0031   -.0045
 20  0.3601  0.3848  0.3824  0.3828  0.3960  0.0359   0.0112   0.0136   0.0132
 25  0.4356  0.4447  0.4418  0.4429  0.4340  -.0016   -.0107   -.0078   -.0089
 30  0.4870  0.4956  0.4934  0.4949  0.5000  0.0130   0.0044   0.0066   0.0051
 35  0.5352  0.5405  0.5395  0.5408  0.5210  -.0142   -.0195   -.0185   -.0198
 40  0.5807  0.5809  0.5815  0.5819  0.5950  0.0143   0.0141   0.0135   0.0131
 45  0.6241  0.6180  0.6204  0.6191  0.6290  0.0049   0.0110   0.0086   0.0099
 50  0.6656  0.6524  0.6567  0.6530  0.6450  -.0206   -.0074   -.0117   -.0080
 55  0.7056  0.6845  0.6909  0.6840
 60  0.7441  0.7148  0.7232  0.7126
 65  0.7815  0.7435  0.7540  0.7391
TOTAL SQD ERROR                                  1.42E-03 1.02E-03 1.03E-03 1.00E-03
TOTAL SQD LOG ERROR                              6.17E-03 3.91E-03 4.07E-03 4.11E-03
CORRELATION COEFF                                  0.9930   0.9949   0.9948   0.9948
R12/2A MIN OFFSET OUTSIDE -30<E<30 USED E=0


  TEST  R12/2A

 Q(STAND) = c*P^n
 Q(OFFSET)= D(P-E)^F      Minimize error in Ln(Q)
 Q(EYER)  = ((P-C)/A)^N   Minimize error in P
 Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD  c^(-1/n)      c          n
          112.417       .0506589   .631619
OFFSET    D^(-1/F)      E          F          B=1/F
          114.147       0          .977525    1.02299
EYER'S    A             C          N          B=1/N
          165.986       -82.9564   2.23251    .447926
LEAST SQ  R             S          T
          .474748       .0178195   -.107178

  P Q-STNDRD Q-OFFST Q-EYER  Q-LSTSQ Q-MEAS ER-STND  ER-OFFST  ER-EYER  ER-LSTSQ

  5  0.1400  0.0470  0.2422  0.3242
 10  0.2169  0.0925  0.2741  0.3140
 15  0.2802  0.1375  0.3081  0.3269
 20  0.3361  0.1822  0.3443  0.3518  0.3360  -.0001   0.1538   -.0083   -.0158
 25  0.3869  0.2266  0.3827  0.3843  0.4050  0.0181   0.1784   0.0223   0.0207
 30  0.4341  0.2708  0.4235  0.4223  0.4410  0.0069   0.1702   0.0175   0.0187
 35  0.4785  0.3149  0.4665  0.4644  0.4520  -.0265   0.1371   -.0145   -.0124
 40  0.5207  0.3588  0.5117  0.5097  0.4850  -.0357   0.1262   -.0267   -.0247
 45  0.5609  0.4026  0.5594  0.5577  0.5630  0.0021   0.1604   0.0036   0.0053
 50  0.5995  0.4462  0.6094  0.6079  0.6140  0.0145   0.1678   0.0046   0.0061
 55  0.6367  0.4898  0.6617  0.6600  0.6620  0.0253   0.1722   0.0003   0.0020
 60  0.6726  0.5333  0.7164  0.7137
 65  0.7075  0.5767  0.7736  0.7689
TOTAL SQD ERROR                                  3.21E-03 2.03E-01 1.83E-03 1.86E-03
TOTAL SQD LOG ERROR                              1.27E-02 1.48E+00 9.41E-03 1.01E-02
CORRELATION COEFF                                  0.9814   0.9862   0.9894   0.9891
```

Appendix C: Instability of Equation 2

The following tests were conducted to see how small changes in the flow or pressure data would cause the C offset term to change. The first set of changes was run on a program for equation 2, on a SHARP PC-1211. All five retests are small variations on the original R22/2A. The only pressure change possible was to omit one or more readings as in R22/2D. The tests R39/2D and R39/2E are variations of R39/2A. All changes are underlined, for comparison purposes.

BLOWDOOR
TEST R22/2A

PA	FLOW
10	0.259
15	0.336
20	0.411
25	0.505
30	0.572
35	0.598
40	0.673

EYERS COEFF
A= 71.9675
B= 1.6557
C= 2.7350
CORR= 0.9963

BLOWDOOR
TEST R22/2D

PA	FLOW
10	0.259
15	0.336
25	0.505
30	0.572
40	0.673

EYERS COEFF
A= 73.9445
B= 1.8932
C= 4.7983
CORR= 0.9981

Pressures at 20 & 35 omitted

BLOWDOOR
TEST R22/2E

PA	FLOW
10	0.259
15	0.350
20	0.411
25	0.490
30	0.572
35	0.598
40	0.673

EYERS COEFF
A= 71.7895
B= 1.5195
C= 0.7756
CORR= 0.9972

BLOWDOOR
TEST R22/2F

PA	FLOW
10	0.270
15	0.350
20	0.411
25	0.490
30	0.572
35	0.598
40	0.655

EYERS COEFF
A= 76.8885
B= 1.6842
C= 1.8616
CORR= 0.9967

BLOWDOOR
TEST R22/2G

PA	FLOW
10	0.259
15	0.336
20	0.411
25	0.505
30	0.572
35	0.605
40	0.650

EYERS COEFF
A= 82.0734
B= 2.0896
C= 5.9439
CORR= 0.9949

BLOWDOOR
TEST R22/2H

PA	FLOW
10	0.259
15	0.336
20	0.411
25	0.505
30	0.510
35	0.598
40	0.673

EYERS COEFF
A= 71.9534
B= 1.2171
C= -4.0436
CORR= 0.9922

TEST R39/2A

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	98.4415	.122966	.469218	
OFFSET	D^(-1/F)	E	F	B=1/F
	81.3443	-14.4382	.833414	1.19998
EYER'S	A	C	N	B=1/N
	81.6437	-15.8428	.87171	1.14717
LEAST SQ	R	S	T	
	.193554	8.78295E-03	.0268443	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.2598	0.3033	0.3042	0.2975					
10	0.3596	0.3671	0.3669	0.3663	0.3680	0.0084	0.0009	0.0011	0.0017
15	0.4349	0.4287	0.4280	0.4293	0.4270	-.0079	-.0017	-.0010	-.0023
20	0.4978	0.4885	0.4879	0.4893	0.4890	-.0088	0.0005	0.0011	-.0003
25	0.5528	0.5470	0.5467	0.5473	0.5400	-.0128	-.0070	-.0067	-.0073
30	0.6021	0.6042	0.6047	0.6041	0.6200	0.0179	0.0159	0.0153	0.0159
35	0.6473	0.6603	0.6618	0.6598	0.6520	0.0047	-.0083	-.0098	-.0078
40	0.6891	0.7155	0.7181	0.7147					
45	0.7283	0.7699	0.7739	0.7689					
50	0.7652	0.8235	0.8290	0.8225					
55	0.8002	0.8764	0.8836	0.8757					
60	0.8336	0.9297	0.9378	0.9285					
65	0.8655	0.9804	0.9914	0.9809					
TOTAL SQD ERROR						7.16E-04	3.72E-04	3.80E-04	3.76E-04
TOTAL SQD LOG ERROR						2.65E-03	1.02E-03	1.02E-03	1.05E-03
CORRELATION COEFF						0.9943	0.9969	0.9969	0.9969

TEST R39/2B

Q(STAND) = c*P^n
Q(OFFSET)= D(P-E)^F Minimize error in Ln(Q)
Q(EYER) = ((P-C)/A)^N Minimize error in P
Q(LST SQ)= R + S*P + T*SQR(P)

STANDARD	c^(-1/n)	c	n	
	83.5319	.114457	.489817	
OFFSET	D^(-1/F)	E	F	B=1/F
	79.5167	-16.0991	.913068	1.09521
EYER'S	A	C	N	B=1/N
	76.7202	-2.51648	.577086	1.73284
LEAST SQ	R	S	T	
	.146372	7.40303E-03	.0436676	

P	Q-STNDRD	Q-OFFST	Q-EYER	Q-LSTSQ	Q-MEAS	ER-STND	ER-OFFST	ER-EYER	ER-LSTSQ
5	0.2518	0.2978	0.2617	0.2810					
10	0.3536	0.3616	0.3512	0.3585	0.3680	0.0144	0.0064	0.0168	0.0095
15	0.4312	0.4244	0.4264	0.4245	0.4070	-.0242	-.0174	-.0194	-.0175
20	0.4965	0.4862	0.4929	0.4897	0.4890	-.0075	0.0028	-.0039	-.0007
25	0.5538	0.5474	0.5534	0.5498	0.5600	0.0062	0.0126	0.0066	0.0102
30	0.6056	0.6079	0.6093	0.6076	0.6200	0.0144	0.0121	0.0107	0.0124
35	0.6531	0.6678	0.6618	0.6638	0.6520	-.0011	-.0158	-.0098	-.0118
40	0.6972	0.7272	0.7113	0.7187					
45	0.7386	0.7862	0.7585	0.7724					
50	0.7777	0.8447	0.8035	0.8253					
55	0.8149	0.9029	0.8468	0.8774					
60	0.8504	0.9607	0.8886	0.9288					
65	0.8844	1.0182	0.9289	0.9796					
TOTAL SQD ERROR						1.10E-03	9.06E-04	9.26E-04	8.70E-04
5.66E-03 3.57E-03 5.07E-03 3.95E-03									
CORRELATION COEFF						0.9918	0.9931	0.9931	0.9934

Appendix D:

The following table shows partial results from the Apple Hill neutral pressure plane testing. In each case, the maximum first floor pressure difference (P_{in}-P_{ont}) is shown for each house.

Other derived data for Phase 1:

For neutral pressure plane testing:

Mean wind speed = 12.88 kph, standard deviation 6.48

Mean temperature difference (T_{in}-T_{ont}) = 17.0°C, S.D. = 4.28

Mean pressure difference (P_{in}-P_{ont}0 = 1.23 Pa., S.D. = 0.986 at first floor levle

For airtightness testing:

Mean wind speed = 17.62 kph, S.D. = 8.89

Derived data for Phase 2:

For neutral pressure plane testing:

Mean wind speed = 13.6 kph, S.D. = 7.36
Mean (T_{in}-T_{ont}) = 1.3°C, S.D. = 2.98
Mean first floor (P_{in}-P_{ont}) = 0.529 Pa., S.D. = 0.435

For Airtightness testing:

Mean wind speed = 14.09 kph, S.D. = 8.18

All this information is relevent to determining what pressures due to wind might be expected at the fan level during airtightness testing. From pg. 7 of the SRC proposal, the dynamic or velocity head of the wind can be given by:

$P = 0.5\ pu^2$ (where p = air density)

Using the Phase 2 data, where stack effect is largely negligible, we have a mean wind speed, at the airport, of 13.6 kph. If this airport wind was unobstructed, then:

$P_{dyn} = 0.5\ pu^2$ (for a wind of 13.6 kph)
$= 8.56$ Pa.

However, from the Lawrence Berkeley Laboratory report COMPUTERIZED, INSTRUMENTED, RESIDENTIAL ANALYSIS (CIRA)

- Sonderegger, Garnier, Dixon
  November 1981
  Section VII, pg. 11.

A standard wind engineering formula is:

$v = v_o \left[\frac{H}{10}\right]^{\gamma}$ where

v = actual wind speed in m/s, at height H (m)

v = wind speed at standard conditions: 10m height, terrain Class 2

α, γ are constants depending on terrain. Apple Hill is terrain class 3 (rural, lowbuildings, trees) or class 4 (urban, industrial), and the constants are:

	γ	α
3	0.20	0.85
4	0.25	0.67

Therefore the wind actually observed at the door fan should be:

For terrain class 3: v = 7.29 kph
For terrain class 4: v = 5.12 kph

disregarding local shielding effects.

for v = 7.29, the corresponding dynamic pressure would be:

$$P = 0.5\ pu^2 = 2.46\ Pa.$$

which is close to the pressures observed during neutral pressure plane testing, and far from the C offset terms generated.

Wind Speed vs Pressure Difference Across Envelope

House	Phase 1		Phase 2	
	Wind Speed (kph)	Highest 1st Floor Pressure Difference (Pa)	Wind Speed (kph)	Highest 1st Floor Pressure Difference
1	17	.88	7	.51
2		1.20	22	.50
3	17	.85	13	.07
4		.80	8	.77
5	30	.85	12	.35
6	7	.80	5	.15
7	7	1.0	8	1.06
11	5	1.15	22	.39
12	8	2.25	22	.29
13	7	.38	8	.19
14	10	.50	18	.80
15	17	2.60		1.73
16	28	.30	15	.24
17	12	.35	7	.11
18	13	.35	26-39	.49
20	10	.70	13	.28
21	15	2.65	10	1.68
22	7	1.68		
23	11	.40	25	.26
24	7	.80	30	1.27
27	13	.95	10	.26
29	15	1.30	0	.34
31	5	1.00	8	.97
32	19	3.80	10	.75
34			10	.64
35	20			
37	7	.40	15	.73
39	15	3.53	10	.35

Appendix E: Airport Wind Speeds During Airtightness Tests

House No.	Wind Speed (kph)	
	Phase 1	Phase 2
1	15	9
2	17	15
3	28	9
4		0
5	7	17
6	32	15
7	15	6
10	15	7
11	40-50	22
12	26-43	26
13	20	6
14	13	7
15	10	20
16	16	19
17	17	7
18		22
20	15	4
21	18	4
22	14	22-40
23	9	20
24	26	15
25		7
27	17	10
28	15	12
29	9	17
30		15
31	7	18
32	23	14

continued

House No.	Wind Speed (kpn)	
	Phase 1	Phase 2
34	15	10
35		30-46
37	9	15
39	11	6
50		22

POOR

QUALITY

ORIGINAL